Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

REPLY COMMENTS OF QUALCOMM INCORPORATED

Dean R. Brenner
Senior Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

March 12, 2013

SUMMARY

Qualcomm is pleased to provide the Commission with additional technical input to assist it in developing a 600 MHz band plan to enable the repurposed spectrum to be quickly and efficiently put to use for mobile broadband. Qualcomm's opening comments detailed why the FCC's alternative 600 MHz band plan — where both the uplink and downlink bands are placed above Channel 37 and separated by a minimal duplex gap — is a technically feasible band plan that can be implemented with a minimum of practical difficulty. A band plan comprised of a 25 MHz uplink band placed directly adjacent to the Lower 700 MHz A (uplink) block, followed by an 11 to 12 MHz duplex gap, and then a 25 MHz downlink band can be integrated into today's smartphones and other mobile broadband devices in a timely manner and thus would allow the FCC to hold a successful forward auction with paired blocks that are truly fungible.

Similar technical considerations led Qualcomm to recommend that any additional spectrum that is recovered over and above the 72 MHz needed to support a 2 x 25 MHz FDD plan[1] be allocated for Supplemental Downlink ("SDL") usage, provided that there is a guard band of approximately 10 MHz between the last full power TV channel and the first SDL block. This approach would establish a duplex gap and a guard band no larger than what is "technically reasonable to prevent harmful interference." Spectrum Act § 6407(b).

This 2 x 25 MHz FDD band plan, with the remainder allocated for SDL use, would allow today's space-constrained smartphones to incorporate support for the paired 600 MHz band without unduly increasing the size of the devices by requiring an additional large antenna and

[1] This 72 MHz of spectrum, which assumes the recovery of at least twelve 6 MHz TV channels, would include a 25 MHz uplink band, a 12 MHz duplex gap, a 25 MHz downlink band, and a 10 MHz guard band to protect the mobile downlink from remaining TV stations.

with a single duplexer, which will minimize device costs. Such a plan also avoids 600 MHz signal harmonics that could interfere with higher frequency bands that these devices also support.

By contrast, we are concerned that a straight 2 x 35 MHz (or wider) FDD band plan would require user devices to incorporate both an additional large antenna and a second duplexer, thereby unacceptably increasing the cost and size of today's space constrained smartphones. A 2 x 35 MHz plan at 600 MHz, however, which divides the band into two adjacent segments both above Channel 37 — a 2 x 15 MHz segment and a 2 x 20 MHz segment — could be supported by a single antenna provided that an adequate tuner is available. This plan would allow the FCC to auction more paired spectrum, assuming that it is recovered from the broadcasters. But, the tradeoff is that this plan requires devices to use a second duplexer and there would be interference within devices if an operator attempted to implement carrier aggregation between the lower 5 MHz uplink portion of the paired 600 MHz band and the upper portion of the PCS band or the lower 10 MHz uplink portion of the paired 600 MHz band and the BRS/EBS band because of lower-order harmonics landing in those latter two bands. Moreover, the single antenna could not support simultaneous operation on the two paired bands.

Qualcomm demonstrated in its opening comments that uplink operations in the lower portion of the 600 MHz band (*i.e.*, below the fifth 5 MHz block below Channel 52) would be troublesome because such operations would introduce lower-order harmonics and significant levels of intermodulation distortion ("IMD") that may interfere to other mobile bands used in today's smartphones and tablets. In addition, uplink operations in the lower portion of the 600 MHz band could impair position location performance in devices. Because of these interference issues, uplink operations in the lower portion of the band would not be spectrally equivalent to, and thus would be worth less than, the spectrum used for uplink operations at the top end of the 600 MHz band, thereby impairing the fungibility of the auctioned spectrum blocks.

For example, as noted above, uplink operations in the sixth 5 MHz block below Channel 52 would introduce a fourth order harmonic that could potentially interfere with BRS/EBS (Band 41) operations in the 2.5 GHz BRS/EBS band. Were the FCC to adopt a band plan that includes as uplink the sixth 5 MHz block below Channel 52, uplink operations in that block may interfere with 2.5 GHz operations that are active on the same user device. Thus, an FDD pairing that includes the 5 MHz block below Channel 52 would not be fungible with, *i.e.*, be spectrally equivalent to, the other FDD pairs. This is why Qualcomm recommended that if the FCC recovers more than 72 MHz of spectrum the additional spectrum should be allocated for SDL purposes, for doing so would satisfy the growing need for additional downlink spectrum and avoid harmonic and IMD interference issues. In these reply comments, Qualcomm includes a detailed listing of all the IMD products, demonstrating in yet another way the very real challenges that uplink operations in the lower portion of the band would pose.

As Qualcomm's opening comments made clear, we believe that it is important that the FCC develop a 600 MHz band plan that enables the use of the existing 700 MHz band antenna system in today's mobile broadband devices to also support the paired spectrum in the 600 MHz band because it is very difficult to find enough additional space in today's smartphones to add another antenna system. The 2 x 25 MHz FDD band plan that Qualcomm recommends can be supported by tuning the 700 MHz band antenna in today's user devices to operate in the 600 MHz band. It is also the case for a 2 x 15 MHz + 2 x 20 MHz plan, if the spectrum is all above Channel 37, but it is not the case for a straight 2 x 35 MHz plan. We remain concerned that a band plan that requires smartphones to add another antenna system just to support the paired band will require all smartphones to become unacceptably large, perform poorly, or both.

In these reply comments, Qualcomm explains in greater detail why there should be no unlicensed TV white space devices or wireless microphones within the duplex gap or within the guard band that separates mobile operations from TV broadcast operations. Indeed, to ensure that the FDD blocks adjacent to the duplex gap are spectrally equivalent to the blocks that are 5, 10, 15 MHz away from the duplex gap, unlicensed TV white space devices and wireless microphones should not be permitted in the gap. Qualcomm's analysis shows that mobile operations in the blocks adjacent to the duplex gap will not only be negatively impacted by such unlicensed or wireless microphone operations in the duplex gap, but it also shows that such operations in the gap will be subject to interference by 600 MHz mobile operations. Harmful interference will occur when the mobile device and the unlicensed devices (or microphones) are tens of meters away or farther, depending on the unlicensed device (white space base station, white space portable, or wireless microphone) and the form of interference (receiver blocking or desense or both). We reached these results even with the most generous assumptions.

This same analysis applies to operations in the guard band between TV stations and the mobile downlink bands. Neither unlicensed TV white space device operations nor wireless microphones should be permitted in the guard band because they will interfere with mobile downlink operations. Nonetheless, as Qualcomm explained in its opening comments, should the FCC decide to permit some type of operations within the duplex gap or lower guard band, wireless microphones are preferred because they are narrowband and geographically-contained, and thus likely to pose far less pervasive interference than unlimited use of TV white space devices. Qualcomm remains concerned about the negative impact on the relative value of the adjacent 5 MHz licensed spectrum blocks should this occur.

Qualcomm appreciates this opportunity to provide reply comments on the *Incentive Auction NPRM*, for this proceeding represents a critical piece of the FCC's multi-faceted efforts to free up much-needed spectrum for mobile broadband. As a leading developer of wireless technologies and chipsets that are fueling the ever-increasing demand for mobile broadband here and abroad, Qualcomm's reply comments offer a deeper technical analysis that it hopes will enable the FCC to develop a successful 600 MHz band plan that allows the repurposed spectrum to be quickly and efficiently put to use for mobile broadband. Our opening comments and these reply comments are based upon a substantial amount of foundational engineering analysis on 600 MHz mobile broadband operations that Qualcomm has conducted to date. Qualcomm will continue its technical work and continue to work closely with all interested stakeholders to drive towards consensus on as many of the technical issues as possible, so that the Commission can adhere to the schedule set forth in the *NPRM*.

CONTENTS

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

REPLY COMMENTS OF QUALCOMM INCORPORATED

QUALCOMM Incorporated ("Qualcomm") is pleased to provide these reply comments on the FCC's *Incentive Auction NPRM*.[2] As Qualcomm explained in its opening comments in this rulemaking,[3] for the incentive auction to be successful, the FCC should develop a 600 MHz band plan and associated technical rules that provide as much clarity and certainty as possible to current broadcast licensees and to future flexible use licensees, *see NPRM* at ¶ 123, because doing so will encourage the highest level of participation from both broadcast licensees and mobile providers and enable the federal government and America to reap the greatest value.

Given the ongoing mobile data capacity crunch, it is critically important that the spectrum repurposed via the incentive auction process be placed online as soon as possible, and Qualcomm has closely focused on how best to incorporate the new mobile broadband spectrum at 600 MHz into existing smartphone and tablet form factors using device components (such as

---

2 *See* Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Notice of Proposed Rulemaking*, FCC 12-118 (rel. Oct. 2, 2012) ("*Incentive Auction NPRM*" or "*NPRM*"); *see also* Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Order*, DA 12-1916 (Nov. 29. 2012) (extending comment date to January 25, and reply comment date to March 12, 2013).

3 *See* Qualcomm Comments (filed Jan. 25, 2013).

filters, duplexers, tuners, and antenna systems) that are reasonably expected to become available within the next 18 to 24 months. This will enable the forward auction winners to rapidly deploy services on the new spectrum and support simultaneous operations using multiple technologies in multiple bands, and thus ensure that 600 MHz forward auction bidders do not discount their bids.

While it is possible to imagine that band plans other than the 2 x 25 MHz FDD band plan that Qualcomm and others recommend may be implemented, our concern is with any plan that is likely to increase the size, cost, and battery demands of mobile devices that include the 600 MHz band because the devices will require unneeded additional antenna systems, and/or additional duplexers, filters, and switches to the extent they also support 700 MHz, cellular, PCS and positioning bands, for example. Implementing such band plans also may require technology that does not exist today and is not under development.

These reply comments provide additional technical input to show the Commission the tradeoffs between various band plans to assist the agency in designing, what, in Qualcomm's view, is the optimal 600 MHz band plan under the circumstances for the forward auction, so the FCC can maximize the value of the newly freed up licensed spectrum for mobile broadband and help ensure that the 600 MHz auction is the Commission's most successful auction ever on a $/MHz/Pop basis. For example, these reply comments explain in detail that allowing unlicensed TV White Space Devices ("WSDs") or wireless microphones to operate within the duplex gap or guard band separating mobile operations from TV broadcast stations will generate interference to and receive interference from mobile broadband operations. Therefore, allowing duplex gap or guard band operations will affect the value of the adjacent mobile broadband spectrum blocks and complicate the auction by preventing the FCC from auctioning fully fungible spectrum blocks. It is within this framework — that is based upon and fully consistent with the core goals of this proceeding[4] — that Qualcomm has done its technical work and analysis relating to the 600 MHz band plan options proposed in the *Incentive Auction NPRM.*

DISCUSSION

I. The FCC Should Implement A Band Plan That Provides Paired Spectrum Blocks That Are Spectrally Identical From An Interference Perspective, And Thus, Fully Fungible

Given the highly complex nature of the simultaneous and tightly interrelated reverse and forward auction processes[5] and because those participating in the forward auction will not know the specific frequency range of the spectrum blocks on which they will place bids, it is critically important that the FCC offer at auction paired spectrum blocks that are effectively identical from an interference perspective, and thus are fully fungible. In addition, to the extent the Commission offers additional spectrum blocks that can be used to support supplemental downlink ("SDL") operations, the FCC likewise should ensure that such blocks are spectrally identical from an interference perspective, and thus equally fungible.

Given that the FDD spectrum blocks will be generic blocks (and not specific frequency blocks),[6] for the auction to be successful, each 2 x 5 MHz FDD block should be spectrally

---

4 *See Incentive Auction NPRM* at ¶ 56; *id*. at ¶¶ 123-24 ("[T]he band plan must provide as much information and certainty as possible, to enable interested wireless providers to make informed business decisions about whether, and how, to bid for and use 600 MHz spectrum. … [A] band plan that balances flexibility with certainty, accommodating varying amounts of available wireless spectrum in different geographic areas [will help to] ensure as a technical matter that wireless providers [can] offer mobile devices that can operate across the country, … minimize device cost and interoperability concerns, and allow for greater economies of scale.").

5 *See Incentive Auction NPRM* at ¶¶ 5, 36.

6 *See Incentive Auction NPRM* at ¶ 56 (where there are multiple blocks of spectrum available in a geographic area, … we could collect bids for one or more "generic" categories of licenses, such as paired or unpaired licenses, in a geographic area. Rather than indicating that a bid is for a specific frequency block in an area, bidders would indicate their interest in, for example, one or more paired 5 megahertz uplink and 5 megahertz downlink (5+5) blocks.").

identical to one another, so the FCC ensure that the spectrum blocks that are adjacent to the duplex gap and guard bands are protected to the same level as the non-adjacent spectrum blocks.[7]

Similarly, the 5 MHz blocks that are identified and auctioned for SDL use should be spectrally comparable to each other, which is accomplished by providing sufficient guard bands to protect the downlink bands from TV broadcast operations and other incompatible services.[8] In this regard, Qualcomm recommends that there be a separation of approximately 10 MHz between the highest full power TV station and any downlink block to avoid saturation of the receiver in the mobile device. As Qualcomm has explained, if the last TV station abutting the first SDL block is a low power TV station, it should be possible to reduce the required frequency separation.[9]

A. Unlicensed TV White Space Device Operations In The 600 MHz Duplex Gap Or Guard Band Will Cause Interference To And Receive Interference From Mobile Broadband Operations

As detailed below, Qualcomm has studied the impact that unlicensed TV WSD operations will have on mobile broadband operations in adjacent bands. Qualcomm has found that not only will unlicensed WSD operations interfere with mobile broadband operations, but such WSD operations also will suffer interference from mobile broadband operations. As a result, the FCC should not permit any such operations within the duplex gap or within the guard band separating mobile broadband operations and TV broadcast operations, because doing so will impact the value of the spectrum blocks that are adjacent to the unlicensed operations.

7 *Cf* Promoting Interoperability in the 700 MHz Commercial Spectrum, *Notice of Proposed Rulemaking*, ¶¶ 5, 32, WT Docket No. 12-69, RM-11592 (rel. Mar. 21, 2012). *See also Incentive Auction NPRM* at ¶ 173.

8 *See Incentive Auction NPRM* at ¶ 64.

9 *See* Qualcomm Comments at iii, 21.

In performing its analysis, Qualcomm divided the 20 TV broadcast channels that span 578 to 698 MHz, *i.e.*, TV Channels 32 to 51, into 24 analysis blocks of 5 MHz each, as shown in Figure 1 below.

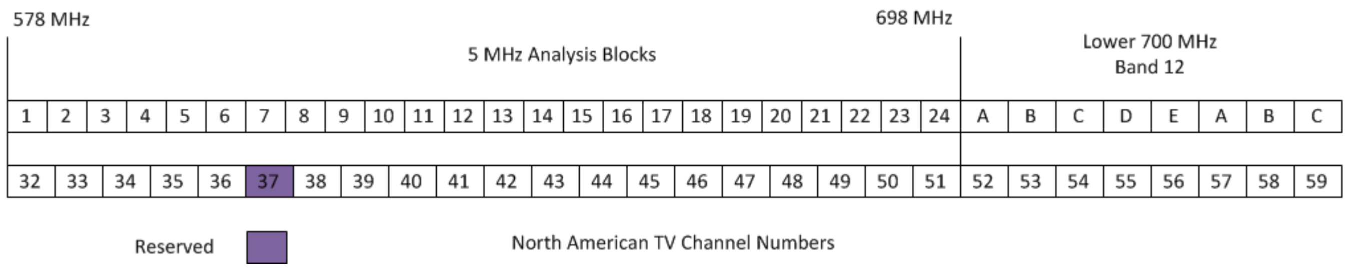


Figure 1. TV Broadcast Channels 32 to 51 Analyzed As Twenty-Four 5 MHz Analysis Blocks

Qualcomm's analysis considered the two situations depicted in Figures 2 and 3 below. Figure 2 shows the two guard bands within the duplex gap, specifically, the guard band to protect the uplink and the guard band to protect the downlink. Figure 3 shows an example of a guard band separating TV broadcast operations from the mobile downlink operations.

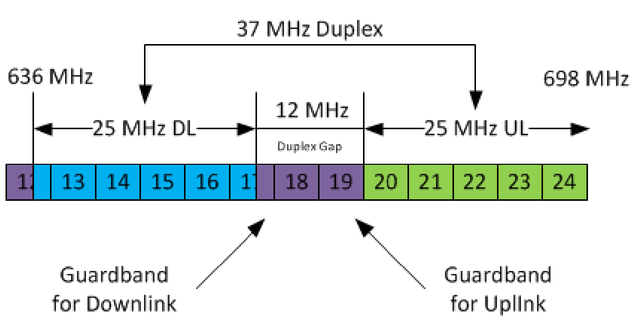


Figure 2. Duplex Gap Guard Bands

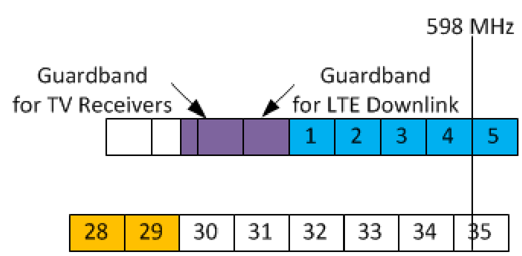


Figure 3. Guard Band Separating TV Broadcast Operations From Mobile Downlink Operations

Qualcomm analyzed three configurations that it determined to be the most susceptible to interference given the operating parameters for WSDs under the FCC's rules and the expected operating parameters for mobile operations at 600 MHz: (1) mobile device receiver suffering desense due to TV WSD out-of-band emissions ("OOBE");[10] (2) mobile device receiver suffering blocking due to TV white space base station adjacent channel power levels;[11] and (3) TV WSD receiver suffering desense due to mobile device OOBE.[12] As detailed below, Qualcomm found that a white space base station can block a mobile user device up to 113 meters away, and that a WSD would suffer significant interference from a mobile device located approximately 140 meters away.

Qualcomm assumed that the TV WSD would operate in compliance with the FCC's rules in Part 15, Subpart H.[13] The TV white space base station power was assumed to be 6 dBW EIRP (using a 6 dBi gain antenna) and a height of up to 30 meters above ground level. The other TV WSD power limits that were used are provided in Table 1 below.

Type of TV bands device	Power limit (6 MHz)	PSD limit (100 kHz)	Adjacent channel limit (100 kHz)
Fixed	30 dBm (1 Watt)	12.6 dBm	-42.8 dBm
Personal/portable (adj. channel)	16 dBm (40 mW)	-1.4 dBm	-56.8 dBm
Sensing only	17 dBm (50 mW)	-0.4 dBm	-55.8 dBm
All other personal/portable	20 dBm (100 mW)	2.6 dBm	-52.8 dBm

Table 1. TV Band Device Power Levels

Qualcomm used the signal propagation model shown in Figure 4 below. For the analysis of LTE to TV WSD device interference, Qualcomm modeled the path loss as n = 2 (free space) and then n = 4; the distance at which this path loss transition occurs is $4 \cdot h_b \cdot h_m / \lambda$, where h_b is the

10 Desense is the degradation in sensitivity of the receiver caused by the interfering source.

11 Receiver blocking occurs where an adjacent channel signal causes the desired signal to be suppressed.

12 Qualcomm recognizes, but did not analyze in detail, the following additional interference use cases: (4) LTE base station suffering desense due to TV WSD OOBE; (5) LTE base station suffering blocking due to TV white space base station adjacent channel operations; and (6) LTE mobile device suffering desense due to TV white space base station OOBE.

13 *See* 47 C.F.R. §§ 15.701-15.717.

height of the white space base station and h_m is the height of the mobile device. The relative heights for the two devices were set as follows: 1.5 meters for the mobile user device and 2.0 meters for the white space base station.

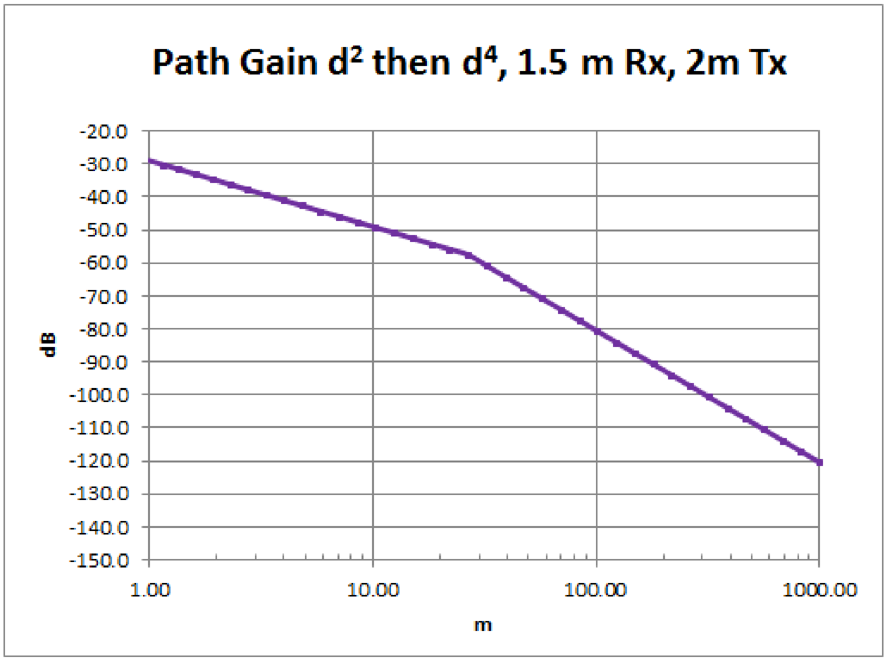


Figure 4. Interference Analysis Path Gain

1. Mobile device receiver suffering desense from a portable TV WSD's OOBE. Qualcomm analyzed this scenario using the signal parameters shown in Table 2 below. The analysis was based upon a 3 dB loss of sensitivity for the mobile device receiver.

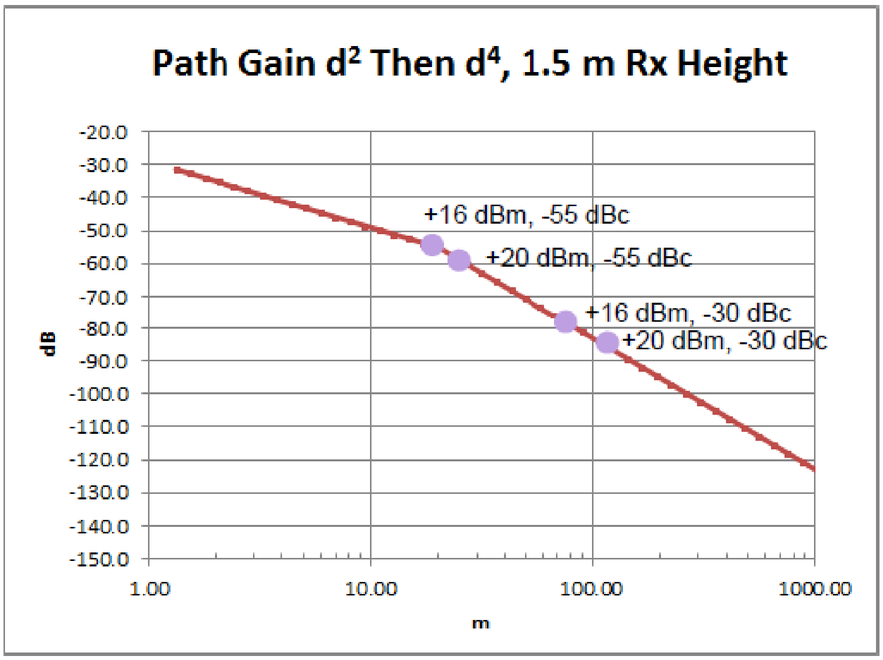
Parameter	Value	Units
RF Frequency	668	MHz
Transmit Height	1.5	M
Receive Height	1.5	M
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	4.5	MHz
Reference Noise Power (kTB)	-107.5	dBm
0 C/N Conducted	-101.5	dBm
Desense	3	dB
Interference Input level 3 dB loss	-98.5	dBm
Antenna Efficiency	-4.9	dB
Radiated Power 3dB Sensitivity Loss	-93.6	dBm
Radiated Power WS UE	20	dBm
First Side Lobe Level	-30	dB Carrier Density
Integrated Loss in Adjacent Channel	0	dB
Radiated Power In Receive Bandwidth	-10	dBm
Path Loss to Achieve 3 dB Desense	83.6	dB
Distance to 3 dB Desense due to OOBE	120	m

Table 2. Parameters Used To Calculate Mobile Receiver Desense Due To WSD OOBE

Qualcomm determined that a WSD operating in an adjacent channel at 100 mW would cause a 3dB loss of sensitivity in the mobile device receiver at a distance of 120 meters and that a WSD operating in an adjacent channel at 40 mW would cause a 3 dB loss of sensitivity in the mobile receiver at a distance of 80 meters where the adjacent channel filter in the WSD provides 30 dB of attenuation.[14] A WSD operating in an adjacent channel at 100 mW would cause a 3 dB

[14] Qualcomm shows the results for WSD portables at two power levels: 40 mW, the level allowed under the FCC's rules when a TV station is on the adjacent channel, and 100 mW, the

loss of sensitivity in the mobile device receiver at a distance of 28 meters. Finally, a WSD operating in an adjacent channel at 40 mW would cause a 3 dB loss of sensitivity in the mobile receiver at a distance of 19 meters where the out of band spectrum roll off and adjacent channel filter in the WSD provides the required 55 dBc of attenuation. These points are plotted on the path gain chart below. The likely roughly 30 dBc attenuation possible without dedicated filtering is shown for reference.



Thus, even with the WSD portable operating at the most restrictive power level currently allowed under the FCC's rules, 40 mW, which applies if there is a TV station on the adjacent channel, and when the WSD portable provides the required 55 dBc of adjacent channel attenuation, which will require filtering or significantly increased power consumption to achieve,

---

level allowed in all other cases. Qualcomm also shows the results for WSD devices providing 55 dB of adjacent channel attenuation as required by the FCC's rules and providing 30 dB of attenuation since that is the level currently typically provided by LTE mobile devices. In all cases, the results show that the WSD will block the mobile receiver when the WSD is a far distance away from the mobile receiver.

the harmful interference to a mobile receiver will occur when the WSD portable is within 19 meters of the mobile receiver.

2. Mobile device receiver suffering blocking due to TV white space base station adjacent channel power levels. Qualcomm analyzed this scenario using the signal parameters shown in Table 3 below. Qualcomm defined the potentially blocked area as the area where the received signal strength exceeds the blocking level set out in the LTE interface specification.[15]

Parameter	Value	Units
Transmit Height	2	m
Receive Height	1.5	m
RF Frequency	668	MHz
Refsens for 5 MHz (Band 12)	-97.0	dBm
WS Blocking Level Refsens + 45.5 dB	-51.5	dBm
Antenna Efficiency (Band 12/17)	-4	dB
Retuning Loss (from 710 to 660 MHz)	.9	dB
Adjacent Channel Integrated Loss	0	dB
Radiated Level	-46.6	dBm
White Space Base Station EIRP	36.0	dBm
Blocking Path Loss	82.6	dB
Distance to Path Loss	113.5	m

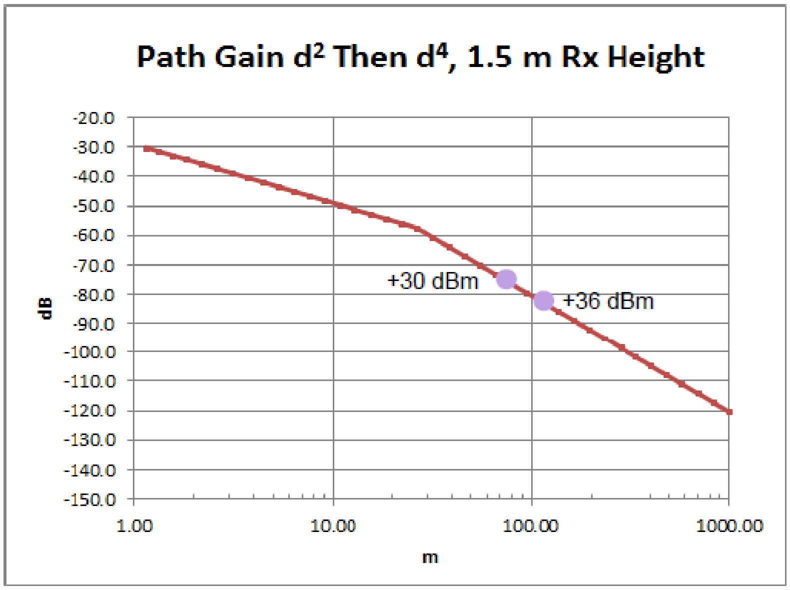
Table 3. Parameters Used To Calculate Mobile Receiver Blocking Due To White Space Base Station Operating In Adjacent Channel

Qualcomm determined that a white space base station operating at 36 dBm EIRP[16] can block a mobile device operating within 113 meters of the base station, and that a white space

[15] *See* 3GPP TS 36.101 V11.2.0 (2012-09) 89 Release 11 ("3GPP 36.101").

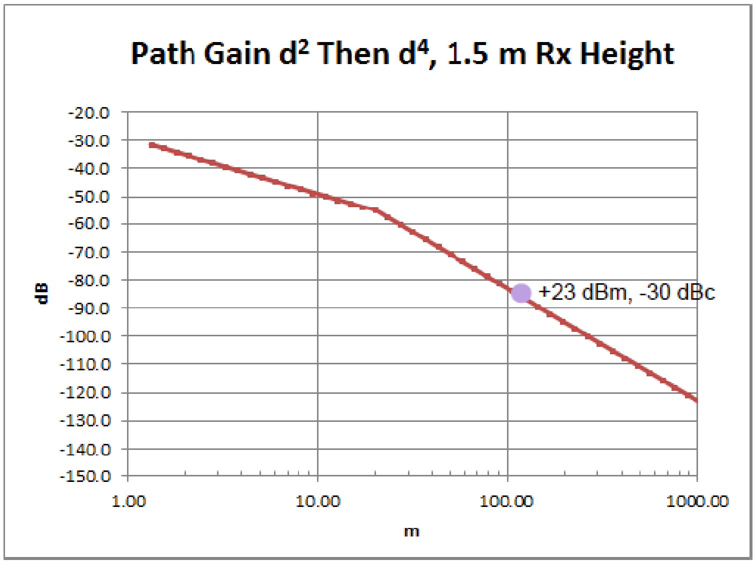
[16] We used 36 dBm for EIRP for the WSD base station by assuming the maximum allowed transmit power of 30 dBm and the maximum allowed antenna gain of 6 dBi.

base station operating at 30 dBm can block a mobile device operating within 80 meters of the base station. These points are plotted in path gain chart below.



3. TV WSD receiver suffering desense from mobile device blocking. Qualcomm analyzed this scenario using the signal parameters shown in Table 4 below. As in case (1) above, this analysis was based upon a 3 dB loss of sensitivity in the WSD receiver. Also, Qualcomm assumed that the RF parameters for the WSD are similar to those for the mobile device receiver. Qualcomm found that a mobile device operating in an adjacent channel at 200 mW can cause a 3 dB loss of sensitivity in the WSD receiver at a distance of 143 meters where the adjacent channel filter in the WSD provides 30 dB of attenuation.[17] This point is plotted in the path gain chart below.

[17] -30 dB of attenuation is achievable with no filter; -55dBc requires a 25 dB filter or approximately 8 MHz offset relative to the band edge.



Parameter	Value	Units
RF Frequency	668	MHz
Transmit Height	1.5	m
Receive Height	1.5	m
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	4.5	MHz
Reference Noise Power (kTB)	-107.5	dBm
0 C/N Conducted	-101.5	dBm
Desense	3	dB
Interference Input level 3 dB loss	-98.5	dBm
Antenna Efficiency	-4.9	dB
Radiated Power 3dB Sensitivity Loss	-93.6	dBm
Radiated Power LTE UE	23	dBm
First Side Lobe Level	-30	dB Carrier Density
Integrated Loss in Adjacent Channel	0	dB
Radiated Power In Receive Bandwidth	-7	dBm
Path Loss to Achieve 3 dB Desense	86.6	dB
Distance to 3 dB Desense due to OOBE	143	m

Table 4. Parameters Used To Calculate WSD Desense Due To Adjacent Mobile Device Operations

Accordingly, white space base station operations in the duplex gap or guard band can cause blocking of mobile reception when the mobile is within an approximately 100 meter radius of the white space base station. Also, WSD portables operating in the duplex gap or guard band can cause 3 dB (or greater) desense of mobile reception when the mobile device is within 19 to 100 meters of each active WSD portable, depending on the actual power levels and filtering of the WSD portable. Moreover, mobile device operations can desense a WSD over a greater area because mobile devices can use higher power levels than WSDs can use. These results show that, to avoid interference to licensed services, unlicensed WSDs should not be permitted in the duplex gap or guard band.[18]

B. Wireless Microphones Also Will Cause Interference To And Suffer Interference From Mobile Broadband Operations In Adjacent Bands

Qualcomm also analyzed the impact the wireless microphones in the duplex gap and guard band can have on mobile broadband operations in the adjacent blocks as well as the reverse effect. This analysis showed that a single wireless microphone operating in accordance with the FCC's Part 74 rules for wireless microphones[19] will cause blocking of the adjacent channel active in a mobile device receiver at a distance of 53 meters and that a collection of 25 wireless microphones will cause blocking in a mobile device receiver operating in an adjacent channel at a distance of 80 meters. Operation of a mobile device will cause 3 dB desense of a wireless microphone up to 143 meters away. In sum, the effect of wireless microphones on adjacent channel mobile device operations is similar to the effect of WSDs on adjacent channel

[18] While these impairments can be partially mitigated by increasing the bandwidth of the guard band and duplex gap beyond what is necessary to protect the licensed mobile broadband services, doing so would obviously decrease the amount of available licensed spectrum for auction and thus violate the mandates of the Spectrum Act. *See* Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, §§ 6402, 6403, 125 Stat. 156 (2012).

[19] Wireless microphones are permitted to operate under Part 15 and Part 74 of the Commission's rules.

mobile device operations, but wireless microphones are likely to be geographically contained and thus the total area of wireless microphones usage likely will be much less than that of WSDs.

1. Wireless microphone(s) impact on 600 MHz mobile device receiver. Qualcomm analyzed the blocking caused by a wireless microphone to a mobile device, specifically an LTE mobile device operating in accordance with 3GPP 36.101 using the parameters provided in Table 5 below. Qualcomm defined an undesired microphone level to be -55 dBm or greater and the desired mobile receive level at -81 dBm (*i.e.*, refsens + 16 dB) or less. Qualcomm found that a single wireless microphone can block a mobile device receiver operating in an adjacent band at a distance of 53 meters.

Parameter	**Value**	**Units**
Transmit Height	1.5	m
Receive Height	1.5	m
RF Frequency	668	MHz
Refsens for 5 MHz Band 12	-97.0	dBm
UE Desired Refsens + 16 dB	-81.0	dBm
WS Conducted Blocking Level	-55	dBm
Antenna Efficiency	-4.9	dB
Adjacent Channel Integrated Loss	0	dB
Radiated Blocking Level	-50.1	dBm
Wireless Mic EIRP	17.0	dBm
Blocking Path Loss	67.1	dB
Distance to Path Loss	53	m

Table 5. Parameters Used To Calculate Wireless Mic Blocking of Adjacent Mobile Device Operations

Qualcomm also analyzed the impact that a collection of wireless microphones would have on a mobile device receiver operating on an adjacent band and found the potential blocking distance to be 80 meters, which is similar to that of a WSD operating at 30 dBm. For this analysis, Qualcomm used a total power level of 31 dBm, derived from the fact that the maximum power is 1.25 W per 5 MHz or 30.8 dBm.

2. Mobile device transmitter impact on wireless microphone receiver. Qualcomm analyzed this scenario using the parameters in Table 6 below. This analysis demonstrates that OOBE from a 600 MHz mobile device transmitter would cause 3 dB of desense to the wireless microphone receiver at a distance of 143 meters. For this analysis, Qualcomm assumed that the RF parameters of the wireless microphone would be similar to the parameters of the mobile device, with the exception of the microphone's 200 kHz receiver bandwidth.

Parameter	Value	Units
RF Frequency	668	MHz
Transmit Height	1.5	m
Receive Height	1.5	m
System Temperature	290	K
Boltzman's constant	1.38E-23	J/K
Receiver Bandwidth	200	kHz
Reference Noise Power (kTB)	-121	dBm
0 C/N Conducted	-115	dBm
Desense	3	dB
Interference Input level 3 dB loss	-112	dBm
Antenna Efficiency	-4.9	dB
Radiated Power 3dB Sensitivity Loss	-107.1	dBm
Radiated Power LTE UE	23	dBm
First Side Lobe Level	-30	dB Carrier Density
Integrated Loss in Adjacent Channel	0	dB
Radiated Power In Receive Bandwidth	-20.5	dBm
Path Loss to Achieve 3 dB Desense	86.6	dB
Distance to 3 dB Desense due to OOBE	143	m

Table 5. Parameters Used To Calculate Impact of Mobile Device OOBE On Wireless Mics

As explained above, the potential interference that wireless microphones would have on a 600 MHz mobile device is similar to the impact that unlicensed white space operations would have on mobile operations. Wireless microphones can block a mobile device receiver that is up to 80 meters away and mobile device OOBE can desense a wireless microphone receiver that is roughly 140 meters away. However, in contrast to white space devices, the deployment of wireless microphones is expected to be limited to performance venues and sports arenas and thus would be geographically confined.

* * *

Accordingly, assuming current FCC technical rules for white space portables and base stations and wireless microphones, the foregoing analysis demonstrates that unlicensed white space operations and wireless microphones can cause harmful interference to mobile devices operating in the directly adjacent bands. The analysis also shows that an LTE mobile device will interfere with TV white space devices and with wireless microphones. Therefore, if unlicensed white space operations or wireless microphones are permitted in the duplex gap or guard band, the mobile broadband spectrum blocks that are directly adjacent to these portions of the band will not be spectrally equivalent to — and thus not fungible with — the blocks located more than 5 MHz away from the guard band and duplex gap. The guard bands and duplex gap should remain clear of any such operations, for the 5 MHz spectrum blocks that comprise the 600 MHz band plan must be "as similar and technically interchangeable as possible to allow for enhanced substitutability across blocks."[20]

Given "that the Spectrum Act constrains the Commission to guard bands 'no larger than is technically reasonable to prevent harmful interference between licensed services outside the

[20] *Incentive Auction NPRM* at ¶ 152.

guard bands,'"[21] the Commission must not expand the size of the guard band or the duplex gap in order to accommodate unlicensed operations inside these quiet portions of the bands. Indeed, the Commission recognizes the need "to provide as much certainty about the operating environment as possible," and the concomitant need to "propose technical solutions to ensure that the spectrum blocks are as free from interference as possible."[22] The only way to meet these goals is to avoid any incompatible operations within the guard band and duplex gap.

Nonetheless, as Qualcomm noted in its opening comments, should the Commission decide to place some operations within the duplex gap or lower guard band, wireless microphones are greatly preferred over TV white space devices because wireless microphones would pose less pervasive interference.[23]

II. A 2 x 25 MHz FDD Band Plan With A Narrow Duplex Gap Similar To The Plan In Figure 12 Of The *NPRM* Is Technically Feasible And Practically Achievable

Based on its technical analysis of potential 600 MHz band plans, Qualcomm recommends that the FCC implement a 2 x 25 MHz Frequency Division Duplex ("FDD") band plan with a narrow duplex gap, *i.e.*, approximately 12 MHz, which is similar to the plan set out in Figure 12 of the *Incentive Auction NPRM* copied below. Qualcomm explained in its opening comments that this band plan can be successfully implemented because it can be readily incorporated into today's mobile devices and minimize device size, complexity, and cost.

---

[21] *See Incentive Auction NPRM* at ¶ 126 (quoting the Spectrum Act § 6407(b)). In addition, it follows that any operations within guard bands themselves (such as TV white space devices and unlicensed devices) cannot cause interference to licensed services.

[22] *See id.* at ¶ 125.

[23] *See* Qualcomm Comments at 23.

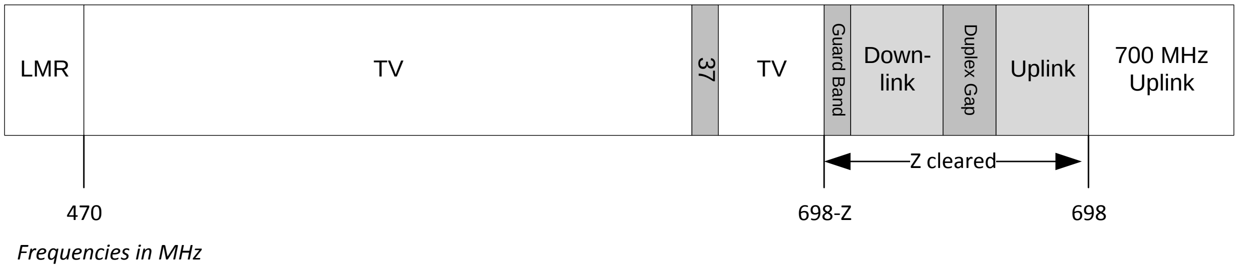


Figure 12 in *Incentive Auction NPRM*

A duplex gap of approximately 11 to 12 MHz is the minimum needed to avoid interference between mobile downlink and uplink, based on the attenuation that the filters can provide.[24] The other critical factor is that a duplex gap that is too wide makes it impossible to support the FDD band with a single antenna.[25] Qualcomm also explained that a guard band of approximately 10 MHz between the last full power (*i.e.*, 1 MW) TV station and the supplemental downlink block is the minimum needed to prevent a TV station from saturating a mobile receiver that is trying to receive.[26]

The FCC's proposed band plan that places the downlink band below Channel 37 and maintains TV stations in the duplex gap above Channel 37 (as depicted in Figures 4 through 10 of the *Incentive Auction NPRM*) is not optimal because it requires the use of two extended guard bands to limit interference between high-powered TV broadcast operations and 600 MHz mobile operations. This sub-optimal plan also requires a very large passband for the paired spectrum that cannot be supported via a single smartphone antenna system. Qualcomm strongly believes that the auction is most likely to be successful if the 600 MHz band plan is designed such that it

24 *See* Qualcomm Comments at 13-15.

25 *See id.*

26 *See, e.g., id.* at 20-21.

can be readily incorporated into existing devices that currently support multiple bands and are already extremely size limited. That band plan is depicted in Figure 12 of the *NPRM*.

A. Analysis Of 600 MHz Signal Harmonics As Well As Intermodulation Products Shows That The 25 MHz Spectrum Block Directly Adjacent To The Lower 700 MHz Band Is Best Suited To Support Uplink Operations

Qualcomm's opening comments presented a detailed analysis of the signal harmonics and intermodulation distortion ("IMD") generated by 600 MHz band transmitters that can potentially impact concurrent mobile operations in higher bands.[27] Qualcomm found that the top five analysis blocks, which span from 673 to 698 MHz, are best suited to support uplink operations.

In analyzing the more than 20 North American bands that can be affected by 600 MHz band signal harmonics, Qualcomm found that there are mobile, unlicensed Wi-Fi, and positioning receive bands that may be potentially jammed by harmonics of 600 MHz uplink operations in each of the 24 analysis blocks that span the 120 MHz from 578 to 698 MHz. However, the top five analysis blocks that span from 673 to 698 MHz are noticeably free from lower order harmonics and IMD products, and thus best suited to support uplink operations.[28]

Qualcomm analyzed numerous technical aspects, including the impact that harmonics from 600 MHz uplink signals would have on other higher band operations (including sensitive positioning bands) that may be in use on the same mobile device, such as a smartphone or tablet, and for Carrier Aggregation ("CA").[29] Concurrent support for multiple bands is a common feature and central to offering CA, which enables significant capacity enhancements.

---

27 *See* Qualcomm Comments at 7-13.

28 In fact, each of the band plans that the FCC proposed in the *NPRM* place the uplink operations at the top portion of the 600 MHz band, i.e., directly adjacent to the lower 700 MHz A block uplink band. *See Incentive Auction NPRM,* ¶ 126, Figures 4 to 15 and associated text.

29 Most wireless operators in the U.S. and abroad are planning to deploy CA technology, which is in the LTE-Advanced standard. CA allows an operator to build a bigger mobile broadband pipe by bonding together two spectrum bands to create one wider band for operations.

Wi-Fi and positioning bands are relevant to the analysis because currently available consumer devices allow multiple physical layers to be active concurrently. Qualcomm's harmonic analysis showed that a third order harmonic from 600 MHz operations may jam the PCS receive band and that a more powerful second order harmonic from 600 MHz operations may jam the Global Navigation Satellite System ("GNSS") positioning receivers that operate within 1164.45 to 1188.45 MHz and 1226.577 to 1249.136 MHz.[30]

The top 5 analysis blocks (*i.e.*, the 25 MHz which runs from 673 to 698 MHz) have only a substantially lower power 8th order harmonic generated by uplink transmissions between 673 to 698 MHz that may impact unlicensed operations at 5 GHz. However, uplink transmissions in analysis block 19, specifically a fourth order harmonic, can impact BRS/EBS (Band 41) operations in the 2.5 GHz band. Based on this analysis, Qualcomm recommended that the upper portion of the 600 MHz band, specifically the 25 MHz-wide band comprised of analysis blocks 20 to 24, is best suited to support mobile broadband uplink operations.[31]

Qualcomm also analyzed the potential intermodulation distortion ("IMD") that 600 MHz operations may create within a user device. IMD is generated where the modulation of signals at two (or more) different frequencies in a system with nonlinearities (such as a smartphone or tablet device) combine to form unwanted additional signals at frequencies that not only appear at the harmonics (integer multiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies. This analysis considered the impact potential of the combination of transmit and receive harmonics to create spurious responses.

---

30 *See* Qualcomm Comments at 11, Table 2.

31 *See id*. at 7-13.

Figure 2 from Qualcomm's opening comments, which is copied below, shows the number of intermodulation spurs greater than -60, -80, and -100 dBm in each of the 24 5 MHz analysis blocks. Figure 2 effectively confirms Qualcomm's harmonic analysis: The lower portion of the band is a particularly poor swath of spectrum in which to place 600 MHz uplink operations. Therefore, uplink operations should be kept in the upper portion of the spectrum band, specifically within analysis blocks 20 to 24 or from 672 to 698 MHz. The impending launch of CA technology, whereby carriers bind one LTE band to another to create wider channels to support enhanced service, would be adversely impacted by uplink operations below 672 MHz.

Moreover, given that uplink operations are best supported in the top five 5 MHz analysis blocks, Qualcomm believes that TDD operations — where uplink and downlink operations occur on the same piece of spectrum — are not well suited for a 600 MHz band plan. Simply stated, it is not optimal to also enable downlink operations in the limited part of the band that is best suited to support uplink operations, as would be the case where TDD is used on the top five 5 MHz blocks.

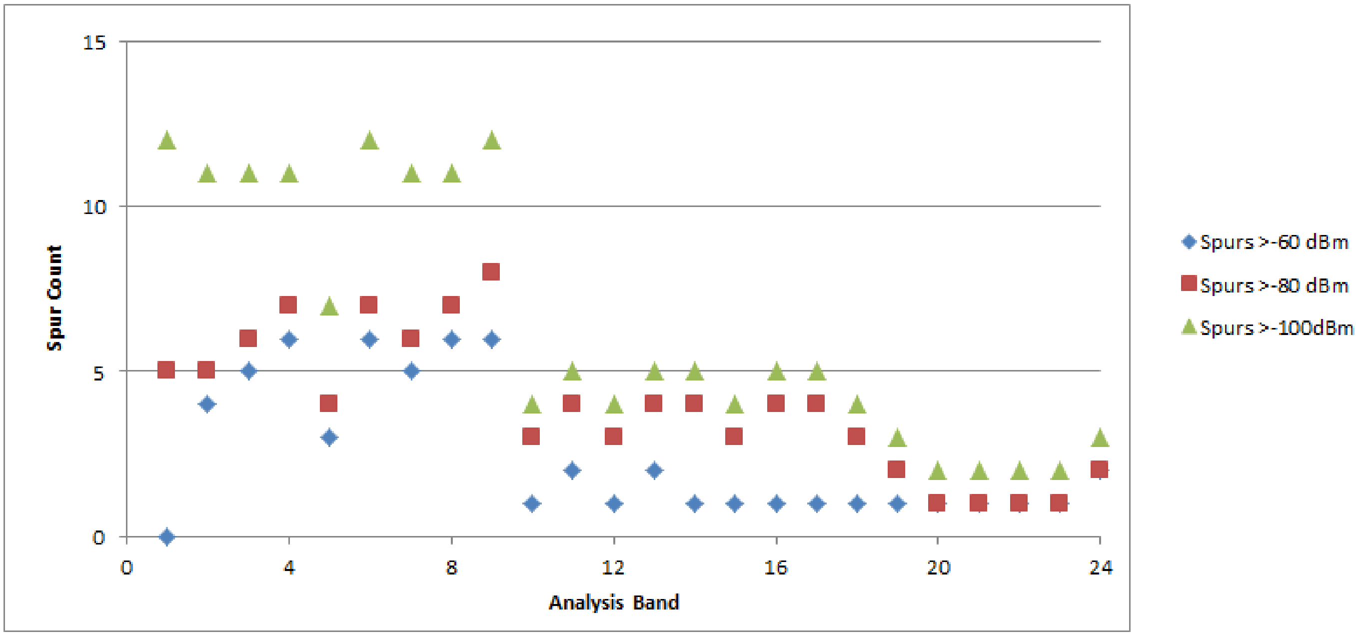


Figure 2. Intermodulation Spurious Analysis Results for the Twenty-Four 5 MHz Analysis Blocks

To further illustrate the fact that the lower portion of the band is particularly poorly suited for uplink operations, Qualcomm presents Table 7 below. This table lists all of the modulation products that could impact operations in bands above 600 MHz. Each transmit and receive pair has a sum or difference combination that creates a receive spur within the receive band of the victim receiver. There are many potential combinations with a lower sum of the receive and transmit harmonic, showing that analysis blocks 10 to 19 are particular problematic uplink frequencies and that analysis blocks 1 to 9 are particularly bad for WAN, geo-location and 3.5 GHz operations.

3GPP Band/ Analysis Block	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
B2														R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1						
B25														R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1	R1+T2 R2+T1						
B41										R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1					
GNSS-L2						R1+T1	R1+T1	R1+T1	R1+T1															
WLAN_2.4_2.48					R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1															
3.5GHz			R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1	R1+T5 R2+T4 R3+T3 R4+T2 R5+T1																	
WCS		R1+T3 R2+T2 R3+T1	R1+T3 R2+T2 R3+T1																					
WLAN_5.17_5.92	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1 R1+T9 R2+T8 R3+T7 R4+T6 R5+T5 R6+T4 R7+T3 R8+T2 R9+T10	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1 R1+T8 R2+T7 R3+T6 R4+T5 R5+T4 R6+T3 R7+T2 R8+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1	R1+T7 R2+T6 R3+T5 R4+T4 R5+T3 R6+T2 R7+T1
GNSS-L5	R1+T1	R1+T1	R1+T1	R1+T1																				

Table 7. Compilation of Modulation Products That May Be Affected By Uplink Operations In A Given 600 MHz Analysis Block

B. A 600 MHz Band Plan Comprised Of A Straight 2 x 35 MHz FDD Plan Or Wider Cannot Be Supported By A Single Antenna System

Qualcomm analyzed the antenna systems that could be used to support operations in the 600 MHz band and believes that it is particularly important that the paired operations within the band be supported by a single antenna system, preferably the same antenna system already currently used in smartphones that support operations at 700 MHz. Qualcomm explained that there is no spare space in today's smartphones, and adding an antenna that is designed exclusively to support 600 MHz operations could require approximately 60% more volume than current 700 MHz antennas.[32] This would substantially challenge current smartphone form factors.

Adding a new low frequency band requires that either a relatively large antenna system be added or an existing antenna (such as that used to support Band 12, 17, or 13 in the 700 MHz band) be tuned to operate in the lower frequency band. If the FCC's 600 MHz band plan requires use of a separate antenna system for 600 MHz, smartphones would have to become much larger in order to perform acceptably, which means that consumers would find these devices much less attractive.

Retuning a 700 MHz antenna does have its costs. A currently implemented 700 MHz band antenna, *i.e.*, an antenna that achieves a 6% 1 dB efficiency bandwidth at 710 MHz, has its 1 dB efficiency bandwidth reduced to approximately 4.6 % when it is retuned to operate at 660 MHz. Qualcomm agrees with Ericsson and IWPC that current mobile device filter technology, including surface acoustic wave ("SAW") filters using Lithium and Tantalum, is limited to a maximum passband of approximately 4% of the passband's center frequency.[33]

---

32 *See* Qualcomm Comments at 13.

33 *See Incentive Auction NPRM* at n.250.

Qualcomm's proposed FDD band plan that is 2 x 25 MHz with a ~12 MHz duplex gap has been derived as the maximum bandwidth for a single duplexer implementation based on the ~4% maximum filter bandwidth limitation.

Accordingly, a straight 2 x 35 MHz — or wider — FDD band plan at 600 MHz would require user devices to incorporate both an additional large antenna and a second duplexer. This would unacceptably increase the cost and size of today's space constrained smartphones. A 2 x 35 MHz plan that divides the band into two adjacent segments that lie above Channel 37 — a 2 x 15 MHz segment and a 2 x 20 MHz segment — could be supported by a single antenna provided that an adequate tuner is available. While this plan would allow the FCC to auction more paired spectrum, assuming that it can be recovered from TV broadcast licensees, the tradeoffs are: (1) that this plan requires mobile devices to use a second duplexer for 600 MHz operations, and (2) there would be interference within the devices if an operator implements CA between the lower 5 MHz uplink portion of the paired 600 MHz band and the upper portion of the PCS band or the lower 10 MHz uplink portion of the paired 600 MHz band and the BRS/EBS band because of the lower-order harmonics and IMD products that land within those latter two bands. Also, this single antenna could not support simultaneous operation on the two paired bands.

CONCLUSION

Qualcomm is pleased to provide additional technical detail on the 600 MHz band plan, which is a core component of the Commission's *Incentive Auction NPRM*. The foregoing reply comments of Qualcomm further support the recommendations in our opening comments. We look forward to continuing to work with the FCC and its industry partners to define a band plan at 600 MHz that can best support mobile broadband operations, and help to ease the mobile data capacity crunch and continue to fuel our remarkable mobile broadband ecosystem.

Respectfully submitted,

QUALCOMM INCORPORATED

By: ______________________

Dean R. Brenner
Senior Vice President, Government Affairs

John W. Kuzin
Senior Director, Regulatory

1730 Pennsylvania Avenue, NW
Suite 850
Washington, DC 20006
(202) 263-0020

Attorneys for QUALCOMM Incorporated

Dated: March 12, 2013